Mallet

Account of a chemical examination of the Celtic antiquities in the collection of Royal Irish Acad.

Dr J W Mallet fm W Dingle
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ACCOUNT

OF

A CHEMICAL EXAMINATION

OF

THE CELTIC ANTIQUITIES

IN THE

COLLECTION OF THE ROYAL IRISH ACADEMY, DUBLIN.

INAUGURAL DISSERTATION FOR THE DEGREE OF DOCTOR,

ADDRESSED TO

THE PHILOSOPHICAL FACULTY

OF THE

University of Göttingen,

BY

JOHN WILLIAM MALLET.

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INAUGURAL DISSERTATION

&c. &c.

The remains of the arts and manufactures of the primeval inhabitants of Northern Europe which time has spared, and which, concealed beneath the earth for ages, the operations of agriculture and various other causes have from time to time disclosed, are interesting in a very high degree as affording us almost the only clue, with the exception of a few vague and uncertain traditions, to a knowledge of the social condition of these Celtic and other tribes who seem to have dwelt over the enormous surface of the North of Europe, almost unknown to the comparatively highly civilized nations of Greece, Italy, and the East.

The archæologist having thus before him the task of reading the history of the aborigines of these countries in the remains of their arts, and discovering from these relics the actual state of physical and intellectual advancement of those who made and used them, it would seem highly probable that much valuable information on this subject might be derived from the chemical examination of the numerous specimens which exist both in public and private collections, as affording us accurate knowledge, at least, of the materials possessed by the people in question, and to some extent even of their modes of working them. Yet, in but few

instances has the assistance of chemical analysis been made use of in the investigation of antiquities, and this, perhaps, for several causes. Not many persons have pursued the study of chemistry along with archæology to a sufficient extent to render the former really serviceable to the latter; and those antiquarians who possess no acquaintance with this valuable engine of research have probably undervalued the importance of its application to their own purpose. Another reason, too, which has undoubtedly contributed greatly to deter the proprietors of fine specimens from permitting a chemical examination of them is the fear, sometimes exaggerated, of the injury likely to be sustained by them in the process. Hence, with the exception of the analysis of some bronzes, but little attention has hitherto been directed to investigation in the direction referred to.

Being anxious to undertake a somewhat extended research of this kind, and convinced that really valuable information could only be obtained by subjecting to analysis a considerable number of carefully selected, and as far as possible, *typical* specimens, I applied to the Council of the Royal Irish Academy, whose collection of Celtic antiquities is one of the most valuable and extensive in existence, for permission to obtain such from their Museum. This was immediately granted, and every facility has been given me in procuring fragments of really fine and illustrative specimens (at the same time taking care to injure none of these in external appearance). The greater number of these articles are metallic; the universal applicability of the metals for purposes of peace and war, of use and ornament, rendering everything calculated to throw light on the materials and processes employed in ancient metallurgy most important in a research of this nature. Some of the others, however, as coloured beads and pigments, are very interesting as illustrative of the state of Art at that remote period.

Commencing, then, with the ancient metals and alloys, the first to be described are the

GOLD ORNAMENTS,

of which class of Celtic antiquities I have seen no record of any previous analyses. In these the collection of the Royal Irish Academy is exceedingly rich, gold torques, gorgets, armlets, and other decorations for the person, being found in great number in Ireland;* indeed, it is said, that scarcely any large tract of land in this country is for the first time cultivated in which there are not some such discovered, and perhaps the larger portion of these are never seen by the public, the finders frequently melting down and selling them for the mere value of the gold.

Of this metal I analysed eight specimens, viz.:

No. 1. Fragments of a "torque" or ornament supposed to have been worn round the neck. It consists of a single strip of thin plate gold twisted so as to form a spiral, this being then bent into a circle, and the ends turned into two small hooks by which the torque was clasped. The ornament had been broken up by the finder into pieces of about two inches long, but when entire it must have been ten inches in diameter. The part examined consisted of the two end hooks. The colour of the gold was a pale, rather sickly yellow, and its specific gravity was 15.377.

No. 2. Fragment of a torque similar to No. 1, and most probably found along with it in the County Sligo; but the locality of neither is certain. This specimen, which was of a rather deeper yellow colour than the last, was from the middle of the torque. Its specific gravity = 15.444.

* All the articles I have examined are from this country, as are, indeed, almost the whole of those contained in the public collection from which they were taken.

No. 3. Portion of a twist of wires of about one-tenth of an inch in diameter each, the whole length of the twist, which is straight, being about six inches. Locality unknown. This *may* have formed part of a bracelet, but there is no second specimen in the Academy Museum, and from its workmanship it does not seem likely to be by any means of so ancient a date as the majority of these gold ornaments. The colour was a very deep rich gold yellow, and the speci c gravity = 18.593.

No. 4. Two fragments of a lunette-shaped ornament made of very thin gold plate, and having a little pattern round each edge. The whole must have measured ten or twelve inches across, and the greatest breadth of the flat plate itself was about two inches. It was, in all probability, a gorget or ornament either for the neck or head, similar to many others preserved in the Museum of the Academy. The locality of the specimen is unknown. It is of about the same colour as standard gold, and of specific gravity 17.528.

No. 5 was a small plate or spatula of gold, about an inch and a half long, and a quarter of an inch wide. It was probably *unmanufactured* gold, not intended for any special use in its present form. It is not known where it was found. The colour is a little lighter than that of No. 4, and specific gravity = 17.332.

No. 6. Fragment of very thin plate gold, which formed part of a boss or concave ornament about four inches in diameter, very like those which cover the ends of the ornaments supposed to be diadems in the Academy Museum. Locality unknown. It was of nearly the same colour with No. 4, and its specific gravity = 15.306.

No. 7. Specimen of Celtic ring-money. It consisted of a bit of gold-wire of about three-fourths of an inch long, and nearly one-eighth of an inch in diameter, bent into a circle,

the ends being quite close, but not fastened to each other. It has been asserted by Sir W. Betham* that these rings used for money were made of graduated weights with reference to the unit of twelve grains, or half-a-pennyweight troy. This specimen weighed 62.13 gr., or 2 dwt. 12 gr., = five of Sir W. Betham's units, and 2.13 gr. over. Colour about the same as No. 5, specific gravity = 17.258.

No. 8. Another specimen of ring-money. It was rather larger than No. 7, but composed of thinner wire. The colour was very much the same with the last, and specific gravity = 16.896. Its weight was 30.04 gr., which is exceedingly close to 1 dwt. 6 gr., or 2½ of Sir W. Betham's units. Hence, it was about half the weight of No. 7. The localities where these specimens of ring-money were found are not known.

The results of the analyses† of the gold ornaments are as follow :—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Gold, . .	71.54	79.48	96.90	88.64	88.72	81.10	86.72	85.62
Silver, . .	23.67	18.01	2.49	11.05	10.02	12.18	12.14	12.79
Copper, .	4.62	2.48	Trace.	.12	1.11	5.94	1.16	1.47
Lead, . .	Trace.	. .	. .	. .	. .	.28	Trace.	. .
Iron, . . .	. .	. .	. .	. .	.02	. .	Trace.	. .
	99.83	99.97	99.39	99.81	99.87	99.50	100.02	99.88

We observe here considerable diversity of composition, and on the whole the existence of a greater amount of alloy than one would perhaps expect from reading the accounts

* Transactions of the Royal Irish Academy, vol. xvii., *Antiq.* p. 7.

† The process of analysis calls for no particular remark, except that the gold was precipitated by making the solution nearly neutral by evaporation, and adding (hot) a slight excess of sulphate of ammonia, which re-agent throws down the metal in the form of a compact sponge, and does not produce the effervescence occasioned by the use of oxalic acid.

of gold ornaments to be found in various books on antiquities, in which they are frequently described as of "pure gold," "fine gold," &c., the colour being apparently very often the only guide to such a belief. Although the analyses here given differ much from one another, yet we find some traces of connexion between the composition of the alloys and the forms into which they were manufactured.

Thus, Nos. 1 and 2 are greatly below the standard of the others, and these are both specimens of the same kind of ornament, the torque, and the only specimens examined. They do not differ much from the composition of the electrum of the ancients as given by Pliny and others.*

No. 6 is about on a par with these as to the quantity of gold, but contains a larger proportion of copper, and less silver.

Nos. 7 and 8 accord very closely with each other, a circumstance particularly interesting from their having been in all probability used as money. That rings of the precious metals were used for this purpose at a very early period there seems to be very little doubt. In Sir W. Betham's memoir on this subject he quotes the fact, that fresco paintings have been found in the tombs of Egypt exhibiting people bringing, as tribute to the king, bags of gold and silver rings, and that on the western coast of Africa rings of copper and iron with expanded ends, exactly resembling some of those discovered in Ireland, were found in use as a circulating medium among the natives, in consequence of which, similar ones have been manufactured

* "Ubicunque quinta argenti portio est, electrum vocatur."—*Plinii Hist. Nat.* lib. xxxiii., c. 4.

"Alia (species electri) ex partibus auri tribus et una argenti conflatur."—*Margerita Philosophica.* Basil, 1523.

to a great extent in England, and sent out as an article of barter.*

As Sir W. Betham has observed, the connexion between the prevalence of this usage in such distant countries is probably to be traced to the great maritime nation of the Phœnicians, the merchant princes of antiquity, whose commerce extended itself over the then known world, and traces of whose presence is to be found so widely diffused.

If, then, as is attempted to be proved in the memoir on this subject before referred to, these rings really represent a metallic currency of graduated weight, referred to a fixed standard; it surely would be a strong confirmation of this opinion, as well as a fact highly illustrative of the advanced commercial condition of the Phœnicians, if it were shown that the ring-money was also of constant composition, and that, therefore, its value was actually represented by its weight. To decide this question, however, more numerous analytical data would be indispensable.

Nos. 4 and 5 in the table also agree very closely, from which we might conclude that the latter, which certainly was not intended for use in the condition in which it was found, was perhaps in process of manufacture into one of the thin, lunette-shaped ornaments, like No. 4, which have been often found in Ireland. Its small size is, however, an objection to this view.

No. 3 is of a much higher standard than any of the others, and approaches fine gold. From its being obviously wire-drawn in the ordinary way through a draw plate, it is probably not nearly so ancient as the other specimens examined. In the earliest ages wire was made by cutting thin plates of metal into strips,† and rounding these upon the

* Cæsar says of the Britons in his time, "utuntur autem nummo aureo aut annulis ferreis ad certum pondus examinatis pro nummo."

† Exodus, xxxix. 3; Homer, Odyss., lib. viii., 273–278.

anvil; and Beckmann, in his History of Inventions* seems to think that the modern method dates no earlier than about the middle of the fourteenth century.

If these ornaments presented no appearance of determined composition, and on the whole contained less silver, it might be supposed that they were in reality made of native gold merely fused and worked into the required shapes; but from the results actually obtained I think there can be no doubt that they are, on the contrary, alloys artificially produced, and probably from determinate quantities of the constituent metals. Hence, no information can be derived from these analyses as to the *geographical source* of the surprising quantity of gold found in the manufactured state in Ireland. In Cornwall, along with the stream tin,† and in Scotland,‡ small quantities of native gold have been obtained, and in Ireland itself, in the county Wicklow,‖ more than 800 ounces were collected in about six weeks. Strabo,§ too, mentions gold (as well as silver, iron, tin, and lead) among the products of Britain. It is, therefore, conceivable that much of the precious metal used in this country may have been found at home; though it would seem from its quantity much more likely to have been brought over by merchants like the Phœnicians, who, in all probability, obtained their chief supply from the eastern coast of Africa, somewhere along which most commentators seem agreed that the Ophir of Scripture existed, if, indeed, the name be not applied generally to the whole of the tropical region reached by the Tyrians by way of the Red Sea.

* Vol. i. Art. Wire-Drawing.

† Carew, Survey of Cornwall, p. 7; Borlase, Natural History of Cornwall, p. 214.

‡ Miscellanea Scotica, p. 228, &c.

‖ Philosophical Transactions, 1796, p. 34.

§ Lib. iv. 30.

SILVER ORNAMENTS.

These are much rarer in Ireland, and, indeed, throughout the north of Europe, than those of gold, and according to archæologists never occur along with antiquities of an earlier date than the commencement of the so-called iron period, that is, about the sixth or seventh century of the Christian era. That silver should be less common among a semi-civilized people than gold, is very natural, if we consider that the latter metal occurs, it may be said, invariably in the native state, while the former is found so but rarely, and not, in Europe at least, in any very great quantity. Apart, too, from the initial difficulties attendant upon the smelting of its ores, the silver, when obtained, is by no means so malleable or easily worked as gold, a circumstance which in some degree accounts for the rude workmanship of very many of the Celtic antiquities of this material.

Of the specimens in the Royal Irish Academy collection I selected and analysed the following eight:—

No. 1. A small ingot of silver, cast in an open mould. It was of a long oval shape, about one-fourth of an inch long and half-an-inch wide. It had two small nicks in one side, close together, as if to mark its weight or value. Its weight was 377.23 grains, = 15 dwt. 12 grs. (+ 5.23 grs.). Hence, if used for money, it would have been equivalent to 31 of the assumed units of ½ dwt. It was a little tarnished by the black sulphuret of silver. Its specific gravity = 10.225.

No. 2. A piece of *hexagonal* wire, very neatly made, probably by hammering, of about one and a half inches long, and one-eighth of an inch in diameter. It was bent into the shape of a horse-shoe, and the ends were cut sharply off, so as to induce the belief that it too may have been used for money. It weighed 103.86 grs. = 4 dwt. 6 grs.

(+ 1.86 grs.), or about eight and a half units. Its specific gravity = 10.253.

No. 3. End of a taper bangle or penannular bracelet of very rude workmanship. Also, perhaps, used occasionally as money. It was very hard, and rather brittle, breaking with a fine earthy fracture of a white colour, verging on yellow. Specific gravity = 8.770.

No. 4 was a specimen which appeared at first sight to be part of a flat silver bracelet or armlet, stamped with the triangular indentations so common on the *silver* ornaments of Celtica and Scandinavia,* and not broken, but cut, across at the ends. On attempting to cut it again, however, it turned out to be a counterfeit, consisting, in fact, of a core of iron covered with an exceedingly thin plate of silver, which was so skilfully joined as completely to deceive the eye even of a careful observer. This imitation of articles in the precious metals has been observed in gold rings, which are sometimes found as a thin shell of the valuable material covering a large core of bronze, or occasionally of lead; but I can find no recorded instance in which silver counterfeits of this kind have been detected. The present example seems certainly corroborative of the opinion, that silver ornaments, apparently of the oldest workmanship, as this was, belonged to an age in which iron had become a plentiful, and therefore comparatively valueless metal, which, in the period of bronze weapons and utensils, it could not have been, and we have abundant testimony, was not. The iron core of this specimen was much corroded, and the silver was tarnished by sulphuret. Specific gravity of the *silver* = 10.379.

No. 5. Fragment of a flat armlet, broken across at the ends, and stamped with square indentations, like those upon a specimen figured by Worsaae.† There were traces of

* Vid. Worsaae, Primeval Antiquities of Denmark, Eng. edit., p. 60.
† Primeval Antiquities, p. 61.

chloride of silver upon the surface, which was much worn. Specific gravity = 10.335.

No. 6. Two fragments of round wire, forming part of a torque large enough for the neck. They are stamped with a small pattern of alternate squares and little pellets in relief. Specific gravity = 10.519.

No. 7. Two fragments of square wire, part of a number of wires twisted into a spiral, so as to form an almost solid cylinder. The twist formerly united two silver boxes covered with filagree work. Specific gravity = 10.468.

No. 8. Part of the hinge of a chased, hollow bangle, resembling common modern Egyptian workmanship; found, it is believed, along with No. 7, and numerous other articles, in a railway cutting near Navan. The silver seems superior in malleability to that of any of the other ornaments examined. Specific gravity = 10.198.

The analysis of these specimens gave the following results:—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Silver, . .	93.93	79.84	37.05	94.69	94.01	92.82	95.87	92.38
Copper, .	5.44	17.73	60.26	3.11	4.34	5.85	3.59	7.21
Gold, . .	0.42	1.34	1.11	1.80	1.31	0.89	0.17	0.30
Lead, . .	. . .	Trace.	0.10	. . .	0.06	. . .	. . .	. . .
Tin, . . .	. . .	. . .	0.61	. . .	. . .	. . .	. . .	. . .
Iron, . . .	. . .	. . .	. . .	0.04	. . .	. . .	. . .	. . .
Sulphur, .	. . .	. . .	. . .	Trace.	. . .	. . .	. . .	. . .
	99.79	98.91	99.13	99.64	99.72	99.56	99.63	99.89

The composition of these silver articles does not seem so varied, nor is there the same agreement between the constitution of the particular specimens destined for the same use, as in the case of the gold ornaments. With the exception of Nos. 2 and 3, the whole set contain from 92 to 96 per cent. of silver, with 7 to 3 per cent. of copper, and

a little gold. The copper might certainly have been derived from the silver ore smelted, and exist in purely accidental quantity; but this seems very improbable, from the extremely small quantity of lead detected, though this metal is a much more frequent concomitant of silver than copper is, and from the fact that the ancients treated their silver ores, just as at the present day, with lead, either in the metallic state or as sulphuret* (Galena), and subjected the alloy thus obtained to cupellation, which latter process would of course remove the copper. The silver was therefore, in all probability, intentionally alloyed. If *all* these ornaments were, though used as such, occasionally employed also as money, as Worsaae† seems to think, and as is supported by several accounts of ancient commercial transactions, one would be led to suspect that here, as with the gold ring-money, something like a recognised standard metal existed when these articles were in use; though this may perhaps be too hasty a conclusion.

Nos. 2 and 3 of these specimens are the only ones which differ remarkably in composition from the others, especially No. 3, which actually contains one-half more copper than silver, though preserving the colour and general appearance of the latter metal. Some, at least, of this large quantity of copper was most probably added in the state of bronze, as shown by the presence of a little tin in the silver alloy. On dissolving the silver in nitric acid, the tin remained behind with the gold, forming a "purple of cassius," of a very good purple colour, verging on red.‡ The uniform pre-

* "Excoqui non potest, nisi cum plumbo nigro, aut cum vena plumbi. Galænam vocant, quæ juxta argenti venas plerumque reperitur."—*Plinii Hist. Nat.*, lib. xxxiii. c. 6.

† Primeval Antiquities, pp. 59, 60.

‡ "Purple of cassius" was obtained in a similar way by M. H. Feneulle (Ann. de Chim. et Phys., xxxii. 320), on dissolving a number of ancient

sence of gold in all the silver articles examined is not surprising, since the ancients were certainly unacquainted with the process of parting.

With respect to the source from whence the silver of the ancient Celts was derived, analysis obviously gives us no more information than in the case of gold. Ores of silver are found in England, Ireland, and Scotland; but they principally consist of argentiferous galena, containing of course but a small proportional quantity of silver, and requiring a good deal of skill to extract the precious metal with advantage. Yet within the historic period the lead ores of Cornwall have been very early worked for silver, and have yielded at times a valuable return.* The great supply of silver of the nations of the Mediterranean was derived from Spain, and was brought from Tartessus (Tarshish. Cadiz.) by the Phœnicians.† Aristotle (De Mirabilib. Auscult.) says that the early mariners of this nation obtained so much silver here, in exchange for oil and other common ship's stores, that they were unable to carry it all away in their vessels, and even used it for anchors (meaning, probably, large mooring-stones or mere weights). And Pliny tells us,—"Reperitur in omnibus pené provinciis, sed in Hispania pulcherrimum."‡ Yet the Phœnicians do not seem to have introduced any large quantity of it into Britain or Ireland. Whether we suppose that they found a greater demand for this metal in the East, and that hence but small quantities found their way into Ireland; or that

Roman silver coins in nitric acid. The results of his rather numerous analyses certainly seem to prove that the Romans employed no standard metal in their silver coinage.

* Lysons; Magna Britannia; Devon, p. cclxxxv.

† "Tarshish was thy merchant, by reason of the multitude of all kinds of riches; with *silver*, iron, tin, and lead, they traded in thy fairs" (i. e. fairs of Tyre).—*Ezekiel*, xxvii. 12.

‡ Hist. Nat., lib. xxxiii. c. 6.

it was in reality never brought to this country as an article of barter, and that all antiquities composed of it were made from British or Irish silver,—it is certainly a curious fact that the Celts possessed so little of a substance which undoubtedly abounded among the nations of the Mediterranean, the method of smelting which was well understood by them, and which was so extensively used as the medium of barter and exchange, that we find its names in Hebrew (כסף) and in Greek (αργυρος), as in the modern French, to be synonymous with money in general.

I may mention here, in connexion with the silver antiquities, a bluish semi-metallic substance, something like steel, used in the inlaying of small shrines, relic cases, croziers, &c., of the middle ages. It has not much lustre, but from its colour contrasts very well with either silver or brass, into works in which latter metal it was frequently introduced, but always in small quantity. I had very little material to operate on, only about one and a half grain, and consequently was unable to do more than analyse it qualitatively. It was of a dark bluish-grey colour, approaching black; very brittle, and exhibiting a small lamellar fracture on being broken. It consisted, as had been previously known, or at least generally supposed, for the most part, of silver; but contained besides, antimony, sulphur, and traces of lead and copper. It may very probably have been made by the partial reduction of some of the antimonial ores of silver, its essential constituents being, I believe, solely silver, antimony, and sulphur.

Having discussed the results of the examination of the antiquities of gold and silver, which principally belong to the class of ornaments, the next of the metallic remains to be considered are those composed of the important alloy which, in the primitive ages, held the same place, as the universal material for all necessary utensils, that iron has acquired in more modern times, namely, the

WEAPONS AND IMPLEMENTS OF BRONZE.

These, it is unnecessary to observe, have been found in enormous quantity in Ireland and the other countries of northern Europe, as well as in Greece, Italy, and throughout the South; the alloy in question having been employed before the introduction of iron to general uses, for all purposes in which hardness, malleability, tenacity, and durability were required.

The Celtic antiquities of bronze, the forms of many of which are very peculiar, and sometimes very beautiful, and their workmanship frequently such as would not disgrace the artificers of the present day, have early attracted the attention of archæologists to the processes used in their formation by the smiths and metallurgists of the epoch to which they belonged. Hence, we find several inquiries, more or less extended, on record, aiming at an elucidation of some of these processes, by the assistance of chemical analysis. Thus, of specimens found in the British Isles, Mr. Alchorn,* His Majesty's Assay-Master in 1774, examined two bronze swords, found in a bog at Cullen, county of Tipperary, and announced as the result, that the metal was "chiefly copper, interspersed with particles of iron, and perhaps some zinc, but without containing either gold or silver," adding, "but I confess myself unable to determine anything with certainty." In 1796, Dr. Pearson† communicated to the Royal Society of London an account of his analyses of seven specimens of bronze, found in the bed of the River Witham, in Lincolnshire, in which he found: copper, 85.7 to 91 per cent.; tin, 14 to 9; and in one instance, 0.3 of silver. In 1816, Professor Clarke‡

* Archæologia, vol. iii. p. 355. † Philosophical Transactions, 1796.
‡ Archæologia, vol. xviii. p. 343.

of Cambridge analysed portions of bronze vessels found near Sawston, Cambridgeshire, and found them to consist of 88 p. c. of copper, and 12 p. c. of tin. This same composition has recently been found for Irish specimens, by Dr. Robinson, of Armagh.* Professor E. Davy,† Mr. O'Sullivan,* Mr. Donovan,* and Mr. J. A. Phillips,‡ have published more complete analyses of antiquities from the latter country, in which foreign metals, as lead, silver, and iron, have been carefully sought for, and their quantity determined; and a similarly accurate examination of Scottish relics of bronze has been made by Mr. Wilson, Hon. Sec. of the Society of Antiquaries of Scotland.‖ Of these investigations, that of Mr. Phillips is certainly the most important as regards Ireland.

The specimens from the Museum of the Royal Irish Academy which I have been permitted to examine were all found in Ireland; and were, as a set, completely illustrative of the principal classes of antiquities belonging to that country. They were sixteen in number.

No. 1. A flat celt, or kind of hatchet; whether used as a warlike weapon or not, seems uncertain. It is the most common implement of bronze found in Ireland.§ This specimen was discovered, it is believed, in the county of Cavan; it is a fine, hard bronze, of a deep brass-yellow colour, the "Celtic brass" of antiquaries. It was in excellent preservation, being scarcely even tarnished on the surface. Specific gravity = 8.631.

No. 2. Another flat celt, with rounded edges; locality

* Proceedings of the Royal Irish Academy, vol. iv. pp. 430–469.

† Wilson's Archæology of Scotland (Edinburgh, 1851), p. 247.

‡ Quarterly Journal of the Chemical Society of London, October, 1851.

‖ Wilson's Archæology of Scotland, p. 245.

§ Vid. Archæological Journal, vol. iv. p. 3, for an extensive memoir on the implement in question by Mr. Du Noyer.

unknown. It was slightly and uniformly corroded on the exterior, and, on being filed, proved to be a *much* softer bronze than No. 1; of a copper-red colour, a little lighter than that of pure copper. Specific gravity = 8.303.

No. 3. A long, hollow celt, resembling in shape specimens which have been found in Denmark; discovered in the county of Wicklow. It was a hard, and rather brittle bronze, of about the same colour as No. 1; slightly and uniformly corroded. Specific gravity = 7.960.

No. 4. A short hollow celt, similar to one figured by Worsaae,* of very good workmanship, and exhibiting scarcely a trace of corrosion; supposed to be from the county Cavan. The metal was very soft, and resembled No. 2 in colour, but was not quite so red. Specific gravity = 8.428.

No. 5. A long spear-head, ribbed upon each side (something like the first figure in Worsaae, p. 30, note); of excellent workmanship, not at all corroded. The bronze was hard and uniform, and had received and retained a very good edge; colour about the same as No. 1. Specific gravity = 8.581.

No. 6. Portion of a spear-head; a flat, thin blade, with a beautiful edge; the surface perfectly smooth and polished, but tarnished of a deep-brown colour, resembling, I believe, the appearance of the bronzes called "Cinque cento." This skin of brown upon the outside was eaten through, in some places, by superficial corrosion. When filed, the metal was found to be exceedingly hard, and of a yellow colour, something deeper than No. 5. Specific gravity = 7.728.

No. 7. A flat scythe, found in the county of Roscommon. Several similar articles were found with this; they were slightly curved blades, of about twelve or fourteen inches long, and tapered in breadth from about three inches at

* Primeval Antiquities, p. 26.

one end, to a rounded point at the other. They had been attached to some handle at the broad end by three rivets. It is supposed by some that they were intended as scythes for the wheels of the ancient war-chariots. The specimen examined was a copper-coloured bronze, of no great hardness, and but slightly corroded on the surface. Specific gravity = 8.404.

No. 8. Portion of a sword-handle; locality unknown. It was part of the characteristic Celtic weapon, in which the handle and blade were cast in a single piece, the former being generally remarkable for its shortness as compared with those of modern times. This specimen was made of a beautiful compact metal, very hard, and of a yellow colour, like that of No. 1, but a little deeper. No corrosion upon the surface. Specific gravity = 8.819.

No. 9. Part of the blade of a sword of the same character as the last, but made from a metal by no means so hard or good. It was similar in colour internally to No. 8, but was considerably more corroded upon the outside. Specific gravity = 8.487.

No. 10. Portion of a dagger, or Irish knife (found near Newry, Co. Down?). A good, hard bronze, very like No. 8 in colour and external appearance, and rather more malleable. It was scarcely even tarnished. Specific gravity = 8.675.

No. 11. Fragment of a chisel made of very inferior bronze, copper-coloured, soft, and not uniform in texture. It contained cavities (produced by air-bubbles in the casting), and was very much corroded; oxide of tin, carbonate of copper, and the *red dinoxide of copper*, were observable on the surface. Specific gravity = 7.896.

No. 12. Specimen of the bronze ring-money, which is found in immense quantity in Ireland. It was a small ring (about one inch in diameter), in form a simple circle, cast

in a single piece, and having no opening, like those in the specimens of gold and silver, by which the rings might be strung together into a chain.* Its weight was 100.53 grs., = 4 dwts. 4.53 grs., or about 8 of the units spoken of above. The bronze was moderately hard, of a deep brass-yellow colour, very little corroded, but having a slight film of green "ærugo" upon the surface. Specific gravity = 8.072.

No. 13. Specimen of ring-money of a larger size than the last, being about two inches in diameter; (locality unknown). It differed from it also in being *hollow*, cast upon a core of fine siliceous sand, which had not been extracted, but remained firmly imbedded in the bronze. There were two small projections on opposite edges of the ring outside, and the core and metal were pierced at these bosses by a hole apparently intended to allow a string to pass, by which the rings might be strung together. If used as money this method of attaching the separate pieces would be certainly less convenient than merely stringing the rings themselves through the centre. Might not these articles have been made as parts of necklaces or other ornaments for the person, though, perhaps, also used occasionally as a circulating medium? The weight of the specimen, *including the sand core*, = 388.43 grs. = 16 dwts. 4.43 grs. = about 32 of the halfpennyweight units. The bronze was very like that of No. 12, but much more brittle. Its surface had been smooth and polished, but was slightly pitted in some places by corrosion. Specific gravity = 8.231.

No. 14. Fragment of a large cauldron or tall vessel of thin sheet bronze. From its size (about 2 feet 6 inches high), and the thinness of the plates of which it was made, it certainly displays a degree of skill in the treatment of bronze most remarkable as existing at a period so early as this doubtless belongs to.

* Specimens having such openings, though rare, do occasionally occur in Ireland. See Sir W. Betham's memoir, already referred to.

The metal is not very hard, but extremely tough, and is of a beautiful rich bronze yellow colour ("gold bronze"), scarcely altered by time. Specific gravity = 8.145.

No. 15. Portion of a small oval-shaped bell, made of a deep yellow bronze; hard and brittle. The surface was rough, but not much corroded. Specific gravity = 8.094.

No. 16. Fragment of a small square bell; the metal about as hard as No. 15, nearly of the same colour also, but not so brittle. It was more corroded, and did not seem so good a material for the purpose. Specific gravity = 7.708.

These specimens being carefully analysed, gave the following results. (In each case a minute qualitative analysis was first made, and the absence of other metals than those afterwards estimated in quantity ascertained) :—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Copper, .	86.98	98.74	88.30	95.64	86.28	84.64	95.85	87.07
Tin, . . .	12.57	1.09	10.92	4.56	12.74	14.01	2.78	8.52
Lead, . .	. . .	. . .	0.10	0.25	0.07	. . .	0.12	3.37
Zinc, . . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Iron, . . .	. . .	0.08	Trace.	. . .	0.31	Trace.	1.32	. . .
Cobalt, . .	. . .	. . .	. . .	. . .	0.09	. . .	. . .	. . .
Gold, . . .	Trace.	Trace.	. . .	. . .	. . .	. . .	. . .	. . .
Silver, . .	0.37	0.06	. . .	0.02	. . .	. . .	. . .	. . .
Arsenic, .	. . .	. . .	Trace.	. . .	. . .	. . .	. . .	. . .
Antimony,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sulphur, .	. . .	. . .	. . .	. . .	. . .	0.03	. . .	Trace.
	99.92	99.97	99.32	100.47	99.49	98.68	100.07	98.96

	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.	No. 15.	No. 16.
Copper, . .	87.94	90.72	91.03	87.24	85.89	88.71	84.78	85.92
Tin, . . .	11.35	8.25	8.39	9.58	13.83	9.46	12.90	11.73
Lead, . .	0.28	0.87	. . .	2.79	Trace.	1.66	2.04	1.72
Zinc, . . .	Trace.	. . .	. . .	Trace.	. . .	. . .	0.06	. . .
Iron, . . .	. . .	. . .	. . .	. . .	. . .	0.03	. . .	Trace.
Cobalt, . .	. . .	. . .	Trace.	. . .	. . .	. . .	. . .	. . .
Gold, . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Silver, . .	. . .	. . .	. . .	Trace.	. . .	. . .	Trace.	. . .
Arsenic, .	. . .	. . .	. . .	. . .	. . .	. . .	0.03	Trace.
Antimony,	. . .	. . .	0.04	. . .	. . .	. . .	. . .	. . .
Sulphur, .	Trace.	. . .	. . .	. . .	Trace.	. . .	. . .	. . .
	99.57	99.84	99.46	99.61	99.72	99.86	99.81	99.37

The composition of these specimens agrees *in general* with that of the articles which have been examined by the authors referred to above, and also accords pretty closely with the quantities synthetically employed by the ancient metallurgists of whose labours we have any account. Thus, Pliny tells us* of the method adopted in his day for making bronze, which, however, he obviously treats of principally as a material for statues and public monuments. "Massa proflatur in primis, mox in proflatum additur tertia portio æris collectanei, hoc est, ex usu coempti. Peculiare in eo condimentum atritu domiti, et consuetudine nitoris veluti mansuefacti. Miscentur et plumbi argentarii pondo duodena ac selibræ, centenis proflati. Appellatur etiamnum et formalis temperatura æris tenerrimi, quoniam nigri plumbi decima portio additur et argentarii vigesima: maximéque ita colorem bibit, quem Græcanicum vocant. Novissima est quæ vocatur ollaria, vase nomen hoc dante, ternis aut quaternis libris plumbi argentarii in centenas æris additis. Cyprio si addatur plumbum, colos purpuræ fit in statuarum prætextis." The analyses also of antiquities not of Celtic origin, as those by Klaproth,† Dize,‡ Mongez,§ Göbėl,‖ and pupils of Erdmann,¶ all approach each other within rather narrow limits, and differ very little from those at present under consideration.

The cause of this general accordance is obvious, namely, that the physical properties required in these alloys of copper and tin are only to be found within a small range of variation in chemical composition. Dr. Robinson, in a communication to the Royal Irish Academy,** gave it as his opinion, that, when used for weapons, the atomic constitu-

* Hist. Nat., lib. xxxiv. c. 9.

† Gehlen's Journal, No. 15, and Journal des Mines, Mars, 1808, p. 161.

‡ Journ. de Phys., 1790.

§ Mém. de l'Instit.

‖ Schweig. 60, 407.

¶ Journ. für pr. Chem. xl. 374.

** Proceedings, vol. iv.

tion of Celtic bronze was constantly 14 Cu + Sn; but though this formula may, and probably does represent the best alloy for the manufacture of implements for warlike purposes, or others in which similar requirements exist, yet it certainly cannot be said that it invariably accords with the actual composition of the antiquities in question, as No. 6 of the analyses in the table is 11 Cu + Sn, while No. 4 is 39 Cu + Sn, and Nos. 2 and 7 contain still more copper, though perhaps the former of these should hardly be considered as bronze.

As on the one hand, we must not conclude that a simple and invariable proportion existed between the component metals of these bronzes, so, on the other, it is erroneous to infer, as Mr. Wilson, in his Archæology of Scotland,* has done, that the absence of such invariable composition necessarily proves, that these antiquities were the work of native artists, who were unable to combine the metals they used with the accuracy and certainty of foreign metallurgists of the same epoch. For, passing over all the difficulties which the modes of reduction of the individual metals, and the impurities consequently retained by them, must have presented to the early manufacturers of *any* nation, and supposing the copper and tin to be used each perfectly pure, the task of producing from these materials an alloy of definite and uniform composition is, even at the present day, one requiring great skill, both in the actual process of melting, and in the previous construction of furnaces, &c., for the purpose, and at the period of the manufacture of the articles in question must be deemed almost impossible of accomplishment.†

* Page 249.

† The principal difficulty consists in the *burning out* of the tin, which takes place with great rapidity on access of air to the melted bronze. The column in the Place Vendôme, Paris, was a remarkable instance of

Besides, we find, in the passage of Pliny above quoted, that there were several mixtures intentionally made use of in making this alloy, in which quantities of tin and lead, differing very considerably from one another, were introduced; and although little be now known of the actual composition of the many celebrated bronzes of antiquity, as the æs Corinthiacum, æs Deliacum, æs Ægineticum, æs Hepatizon, Mossynæcum, &c., yet the very existence of these distinctive appellations is a strong presumptive proof of their having possessed marked differences in physical properties, and therefore in the chemical constitution upon which the former mainly depend.

Hence, I conceive, that the observed variations of composition between the various bronze antiquities found in these countries by no means negative the possibility, to say the least, of their having been the work of a single people, and that one far advanced in the art of metallurgy, for the epoch to which these articles are referred.

Yet, although these differences of composition are, probably to a very great extent, owing to the want of sufficient skill to produce from the same materials a uniform result, and are therefore to be looked upon as unintentional; yet some marks of design may be traced in the discrepancies between articles intended for different purposes. Thus we find two of the celts (Nos. 2 and 4), and the war scythe, (No. 7), to consist almost entirely of copper, the quantity of tin amounting in No. 2 to only 1.09 p. c., a proportion so small, that it might be supposed to be derived merely from the addition of fragments of old bronze to the copper.

The only analysis of Celtic bronze containing so much copper, that I have seen, is that of a broken spear-head,

mismanagement in this respect, almost the whole of the tin having disappeared from some of the metal employed.

found in Ireland, examined by Mr. Phillips,* from which he obtained 99.71 per cent. of copper, and 0.28 of sulphur. The composition of the metal used in casting the celebrated Quadriga of Chios (better known in this country as the Horses of St. Mark's, Venice), as determined by Klaproth,† was also very near that of the present specimens; being 99.13 per cent. copper and 0.87 tin. Some ancient nails analysed by the same chemist,‡ and Greek and Roman coins examined by Mr. Phillips,§ and pupils of Erdmann,‖ also appear to have been made from nearly pure copper.

The other celts (Nos. 1 and 3), one of the spear-heads (No. 5), and one of the swords (No. 9), agree pretty closely in composition; containing about 87 or 88 per cent. copper, and 13 or 12 of tin, if we disregard all traces of foreign metals. This is the composition assigned by Dr. Robinson as the best for the purpose; and his opinion seems, in fact, borne out by the results before us, as the specimens numbered 1, 3, and 5 were certainly very far superior to most of the others in hardness, uniformity, and toughness combined; and the alloy having this constitution seems fairly to be considered as the normal one, *at least where other metals than copper and tin are present only in most insignificant quantity*. For 2 or 3 per cent. of a foreign metal, as lead, seems to exercise a very great influence in changing the character of the whole. Thus, the sword (No. 8) in which the tin amounted to only 8.52 per cent., but which contained besides 3.37 per cent. of lead, fully equalled the weapons just mentioned in hardness, and, perhaps, even exceeded them in malleability and facility in working.

* Quarterly Journal of the Chemical Society, loc. cit.

† Beiträge, vi. 89. Gehlen's Journal, No. 15.

‡ Gehlen's Journal, loc. cit. § Loc. cit.

‖ Journ. pr. Chem. xl. 374.

The second of the two spear-heads (No. 6) was exceedingly hard, and had received a good edge, but it had not the same toughness as the others, and had broken across without bending; hence so large a proportion of tin as it contains, 14.01 per cent., does not seem to yield a metal so well adapted for weapons as a smaller quantity.

The two daggers, or knives (Nos. 10 and 11), agree very closely in composition, yet the difference in physical properties is most marked. No. 10 was a bronze of excellent quality, a little softer than No. 8, but still sufficiently hard, tough, and uniform, and not at all corroded; while No. 11 was soft, full of cavities, not uniform in texture, and was covered with the results of corrosion. (Of course in this, as in every other instance in which we examine the corrosion of metals, regard ought to be had to the situation in which they have been discovered; but, unfortunately, in the present case information on this head is entirely wanting.) Additional analyses of very inferior bronzes, and those which have suffered most by corrosion, taking care to examine fragments taken from different parts of the same article, might yield results of interest, and possibly, indeed, of practical importance.

The cauldron, or vase, of thin sheet bronze (No. 14) we find to have contained about the same per centage of copper as the bright yellow-coloured alloy for weapons (rather more than 88 per cent.) but not quite so much tin, its place being partly supplied by about 2 per cent. of lead, which tends to make it more malleable and easily beaten out.

The two specimens of ring-money (Nos. 12 and 13) contain quantities of copper differing by nearly 1.5 per cent., while the proportion of tin varies still more, being 9.58 per cent. in the former, and 13.83 in the latter. In the one we find 2.79 per cent. of lead, but in the other a mere trace of that metal is perceptible. Hence it is obvious

that, as far as these specimens are to be considered as representing the ancient Celtic currency of bronze, no very accurate standard of alloy was observed in its production. This is not surprising; the formation of such a definite and constant alloy being, as above mentioned, attended with much difficulty, and the inferior value of the material rendering it an object by no means so important as in the case of gold or silver. The rings being merely cast, and not struck like coins of an ordinary character, the physical properties of the metal did not need so much attention as in the case of arms or other implements, where these were of the first importance.

The samples of bell-metal examined, numbered 15 and 16, differ but little from each other. The quantity of copper is considerably greater than that generally employed at the present day. This was, perhaps, owing to the desire of the early artists to avoid brittleness in the metal. The composition of these specimens is very simple, copper and tin being, as in all the other ancient bronzes, almost the sole constituents. Modern British bell-metal is much more complex, containing, according to Thomson,* 80 per cent. of copper, 5.6 of zinc, 10.1 of tin, and 4.3 lead.† These Irish bells, it is scarcely necessary to say, are of much more recent date than the bronze weapons, belonging, it is believed, to about the eighth or ninth century.

With respect to the foreign metals found in minute quantities in these articles, although, with the exception perhaps of lead, they may all be fairly considered as accidental, and merely introduced as impurities in some one of the princi-

* Ann. Phil. 2. 209.

† M. Girardin found the composition of the "cloche d'argent," an ancient bell at Rouen, to be, copper, 71; tin, 26; zinc, 1.80; and iron, 1.20 = 100. (Ann. de Chim. et Phys. 50. 205.) The quantity of copper here is exceedingly small.

pal constituents, yet they by no means deserve to be neglected, as they may occasionally, in the consideration of antiquities, yield some collateral information. The lead which is found in many of the specimens, and has been previously detected in much larger quantity in some bronzes, might have existed as an impurity of the copper, but was more probably added either intentionally in the separate state, or in old bronze, which, particularly when used for statues, often contained this metal. Zinc was only observable in minute traces in three of the bronzes, but its presence in these was distinctly ascertained. In all probability, it was introduced along with the copper, and was derived from blende occurring along with the ore of that metal, and imperfectly separated from it. Though found in large quantity in some early Roman coins, I believe it has not before been detected in Celtic bronze. Iron might have come in with either of the constituent metals, and has been observed in previous analyses. Indeed, from its universal diffusion in nature, its presence in these alloys is not surprising. Our finding the rarer metal cobalt, though only in two instances, is more remarkable; these, however, are not the only antique bronzes in which it has been observed, as Mr. Phillips, in his valuable paper referred to above, notices it and nickel as occurring in several early coins, and in one Irish specimen, a celt, to the amount of .34 p. c. (with a trace of nickel). The minute quantities of the precious metals were perhaps derived from fragments adhering to old ornaments of bronze, which were afterwards remelted. It has been supposed that traces of silver found in one or two previous analyses were owing to the lead not having been refined, and this was probably often the case, but in two instances here (Nos. 1 and 2), it could not have been so, as no lead was present. Arsenic and antimony

have, I believe, not been hitherto noticed in similar alloys,* and existing in such very small quantity, are not easily detected; but by employing a separate portion of bronze for the purpose I determined accurately the question of their presence or absence. The fact of traces of them being found in the alloy is, of course, one easy of explanation. Indications of sulphur (and of carbon, by Mr. Donovan) have been observed in several specimens previously analysed; these, and the traces of arsenic and antimony are interesting, as rendering it at least probable that some of the copper used by the ancients was smelted from sulphuret of copper or copper pyrites (probably the chalcitis or misy of Pliny), or other ores of the same class, and that native copper and malachite did not, as some authors seem to suppose, constitute their only sources of the metal.

The question, from what countries were the copper and tin employed to such an immense extent by the nations of antiquity derived, is one of great interest, and has been already treated of, especially with reference to the source of the tin, by numerous authors of celebrity. They seem generally agreed, that the former of these metals was discovered and extracted at a very early period in several places in the south and east of Europe, and adjoining portion of Asia. At the period of the Trojan war, and at the time of the building of Solomon's temple, the supply of copper must have been most abundant, and the name frequently occurs at a still earlier epoch in the Pentateuch. The art of casting statues of bronze is ascribed by Pausanias to Rhœcus and Theodorus of Samos (about 700 or 800 B. C.), at which time it must of course have become quite common, though we have but little knowledge of the localities from which

* Except in one instance. Jahn (Ann. Pharm. 27. 338) found 8.22 p. c. of antimony in an ancient weapon from the ruined castle of Henneberg.

it was derived. When Pliny wrote, its principal sources were Cyprus, Campania, Gaul, and Spain, especially the last-named country. Although England now supplies a very large proportion of all the copper made use of in the world, there are no traces in history of any having been smelted here so early as the Celtic period, and the contrary seems to be proved by a passage in Cæsar, de Bell. Gall.,* where he says of Britain: "Nascitur ibi plumbum album in mediterraneis regionibus, in maritimis ferrum, sed ejus exigua est copia, *ære utuntur importato.*" Strabo also† enumerates gold, silver, iron, tin, and lead, among the products of Britain, but does not mention copper, the sixth of the then well-known metals, which, doubtless, he would not have omitted had he known of its being found here.

It appears certain, that by far the largest portion of the tin used in the manufacture of the bronze of antiquity was brought from Cornwall by Phœnician merchants, and by them distributed over the south of Europe, Syria, and Asia Minor. Strabo‡ and Pliny§ indeed state that it came from Spain, and tinstone does exist in that country in the province of Gallicia, but the quantity there found is not likely to have supplied the enormous demand for this metal; and their account is easily explained by the fact of the great commercial depot of the Phœnicians in the west having been situated at Tartessus (the Tarshish of Scripture) in the south of Spain, near Gades (now Cadiz). From this place the tin was brought to Tyre itself, as we learn from the book of Ezekiel‖ in the remarkable and important passage in which the merchandize of that great city is described

* Lib. iv. c. 34.

† Lib. iv. 305.

‡ Lib. iii. p. 219. ed. Almel.

§ Lib. xxxiv. c. 16.

‖ Ch. xxvii. ver. 12. In the next verse we are told that Tyre derived her "vessels of brass" (copper), as well as the "persons of men," from Javan, Tubal, and Meschech, names generally supposed to mean Greece and the north-eastern portion of Asia Minor.

—" Tarshish was thy merchant by reason of the multitude of all kind of riches; with silver, iron, *tin,* and lead, they traded in thy fairs." And the testimony of almost all the ancient writers who allude to the subject goes to show that this metal came from distant islands beyond the Pillars of Hercules, of which, however, they knew very little more than the name, Cassiterides; (which, as Professor Tychsen has ingeniously remarked,* from its probable connexion with the prefixes of many of the ancient British names—as Cassi, Cassivelaunus, is an additional evidence as to the real locality of these islands). It has been often observed, that the Phœnicians endeavoured to throw a mystery over this their distant commerce, guarding their monopoly with the most jealous care, and hence the ignorance on the subject amongst those who were their customers.†

Though Pliny‡ tells us of tin, " Nulli rei sine mixtura utile," yet it was obviously well known in the separate state, as even in Homer we read of the breast-plate of Agamemnon:

" Τοῦ δ' ἤτοι δέκα οἶμοι ἔσαν μέλανος κυάνοιο,
Δώδεκα δὲ χρυσοῖο, καὶ εἴκοσι κασσιτέροιο."

Il. xi. 24.

and the same poet mentions metallic tin in several other places. Hesiod does so too, and Aristotle and Pliny speak of it as a known and in their time common substance. Yet antiquities of this metal are very rare in England and Ireland; indeed there have been, I believe, but three instances recorded in which such have been found—all in England.§ Hence a single specimen found in the collection of the Royal

* In Beckmann's Hist. Invent., vol. ii. p. 209.

† Aristotle, however, the accuracy of whose accounts of subjects of natural history is truly surprising, distinctly mentions " τὸν κασσιτερον τὸν Κελτικὸν."—*De Mirab. Auscult.*

‡ Loc. cit.

§ Phil. Trans., vol. xxiii. p. 1129, and vol. li. p. 13. Archæologia, vol. xvi. p. 137.

Irish Academy acquires considerable interest. It constituted the *core* of a hollow bronze ring of about four and a half inches in diameter, the thickness of the ring being about half-an-inch.

I easily recognised it as tin by its colour, and the resistance it offered to the knife, and on examining it chemically found it to be nearly pure, containing mere traces of iron and lead. Where partially exposed to the atmosphere it had acquired a coating of peroxide. From the way in which it is attached to the bronze, and the character of the latter, it would seem undoubtedly to belong to the same period with the other early bronze antiquities in the Museum.

In the same collection there is an earthen vessel apparently intended to be placed in the fire, in which were found several small fragments of bronze very much corroded, a brown earthy powder in which particles of the "ærugo" of bronze were observable, and a bit of a white metal of considerable lustre, and exhibiting a somewhat lamellar structure. This latter was hard and very brittle, so as to be easily reduced to powder in a mortar. There were no traces of corrosion on the surface. Specific gravity = 8·107. On analysis it gave in 100 parts.

Copper, ...	66.12
Tin, ...	30.62
Silver, ...	.13
Antimony, ...	1.91
Sulphur, ...	.11
	98·89

Thus, though an alloy of copper and tin, it differs totally from bronze in the proportion of its ingredients. The only analysis I have seen which comes near this is that of an antique Roman mirror by Klaproth,* in which he found, copper,

* Scherer's allgem. Journ. d. Chemie., No. 33.

62; tin, 32; and lead, 6 = 100. Whether the Irish alloy was intentionally made to be used for some similar purpose, or the proportion of tin was accidentally large, and the specimen was about to be remelted and perhaps copper added, is not easy to determine. The pulverulent substance found in the same vessel was neither an ore of any kind, nor a furnace product, but appeared on examination to have been merely dust of an earthy character mixed with the results of bronze corrosion, (probably the sweepings of a workshop or some such place.) The vessel and its contents undoubtedly constitute an interesting relic of early metallurgy.

Although *Zinc* in the metallic state was unknown, at least until the twelfth century, it seems certain that some of its ores were worked and used for making aurichalcum or brass at an extremely early period, the valuable properties of that alloy being well known and appreciated in Aristotle's time, although he speaks of it under the name of *χαλκὸς Μοσσύνοικος* as a rare variety of bronze. This Pliny also considered it, and it seems never to have come into common use amongst either the Greeks or Romans. Hence it is not surprising that no example of a brazen article of decidedly Celtic manufacture has yet been discovered. I analysed a fragment of a shallow basin from the district of Castlebernard, Co. Cork, recently presented to the Academy Museum, and found it to contain:

Copper,	72.58
Zinc,	25.29
Iron,	1.16
Lead,	.02
Tin,	Trace.
	99.05

The specimen was soft, of a bright brass-yellow colour, and specific gravity = 7.717. From its form, however, and composition, which is quite that of ordinary modern brass,

it is probably of very little antiquity, and does not at all belong to the same class as the really Celtic articles in the Museum ; and that therefore an alloy of copper and zinc of equal age with the latter is still to be sought for. Amongst German antiquities Göbel* found some of this composition, but I do not know to what date or people his specimens are assigned by archæologists.

Lead is another of the metals which was extracted from its ores and applied to many of the purposes for which it is used at the present day, at probably a period nearly as ancient as that of the introduction of copper. With the exception of native metals, no ore would be more likely to have come under the notice and attracted the attention of primitive metallurgists than galena, the commonest form in which it occurs, and from this the extraction of the lead itself would present scarcely any difficulty even with the rudest means for smelting. Mention is accordingly made of the metal amongst the Egyptians, Phœnicians, Greeks, Romans, and other nations of antiquity, who not only used it in its separate state for water-pipes and other mechanical purposes, but were also acquainted with the method of employing it in the refinement of gold† and silver.‡ In Britain, particularly in Derbyshire, numerous remains of lead-workings belonging to the time of the Roman invasion have been discovered, but I have seen no account of any relics of this metal of similar antiquity having been found in Ireland; and in the Museum of the Royal Irish Academy the only traces of lead that I could find were the cores of one or two reliquaries of thin gold plate or foil which are, I believe, considered as specimens of mediæval art. The interior surface of one of these cores, which was hollow, was considerably corroded, being covered with a greyish crust of carbonate, the pro-

* Schweig. 60. 407. † Theognis,—Γνωμαι. l. 1101.

‡ Jeremiah vi. 28. Pliny, lib. xxxiii. c. 6.

duction of which was probably accelerated by the contact of the gold. Some ancient lead from an abbot's coffin in the Cathedral of Christ Church, Dublin, which was deeply pitted by corrosion, yielded traces of sulphate along with the carbonate upon its surface, and on cupellation of the metal itself left a minute bead of silver.

Of weapons and implements of *Iron* numerous specimens have been found in Ireland, as well as throughout other parts of Northern Europe, and the period of their first introduction is looked upon by Celtic and Scandinavian antiquaries as a distinct epoch in the history of the early inhabitants of this part of the earth, marking the commencement of the Teutonic or Iron period, and probably about contemporaneous with the military expeditions of the Romans hither. Of these specimens I examined four, namely:—

No. 1. A sword found at Kilmainham, near Dublin. It is long and straight, adapted for both cutting and thrusting, and is one of those examined by M. Worsaae, the eminent Danish archæologist, on visiting the Museum a few years ago, and declared by him to agree perfectly with the Norse swords preserved at Copenhagen and Stockholm. The blade was covered by a thick coat of rust, on removing which the remaining metal was re-forged as the simplest way of determining its character, and turned out not to be steel, but moderately good soft iron incapable of being hardened by quenching when hot in water. On solution in dilute sulphuric acid it left a very slight black sediment consisting of carbon with traces of phosphorus.

No. 2. A knife, also found at Kilmainham; still more corroded than the last, there being, in fact, very little metal left. The fracture was very close-grained, and of a bluish-white colour; and, on re-forging, it proved to be steel of an inferior quality, leaving, on solution in a dilute acid, carbon containing phosphorus and silica, the quantity of which was,

however, not determined. The specimen is, however, probably a very modern one, and ought not to be compared with the others here described.

No. 3. A nail from Dunshaughlin in the Co. Meath. It was not nearly so much corroded as the last two specimens, and the rust was hard and closely adherent, whereas that on the sword and knife was quite loose and easily detached. On the crust of oxide some traces of the blue phosphate of iron were observable, and more was to be found on breaking it off from the metal. The latter, on re-forging, proved, as might have been expected, to be soft iron, containing, I found by chemical examination, a large proportion of phosphorus as compared with the other specimens.

No. 4 was another knife, of a small size, narrow-bladed, and thick on the back, discovered at Strokestown in the Co. Roscommon. It was covered by very little rust as I got it, but had apparently had some corrosion previously removed. It consisted, not of steel, which it rather resembled in appearance, but merely of malleable iron of excellent quality, which dissolved almost perfectly in dilute sulphuric acid, leaving a barely visible trace of carbon, and affording no indications of phosphorus.

From these experiments we see, so far as their limited number renders it allowable to judge, that the really ancient weapons of this kind found in Ireland do not consist of steel; which would be in itself an interesting fact if confirmed by further investigation, as showing that the early Scandinavians and Celts were able to make good malleable iron in the first instance, but were not acquainted with the method of giving it the superior hardness and elasticity of steel by any after-process, though it is plain from many passages in the Greek and Roman authors,* that the lat-

* See Aristotle, *De Mirab.* Pliny, lib. xxxiv. c. 14. Dr. Pearson (Phil. Trans., 1796) found all the supposed iron weapons from Lincolnshire which he examined to consist of steel.

ter substance was well known to them.* The subject, however, demands further investigation.

Having now concluded the account of the metallic antiquities, I may mention the results of my examination of some other objects, principally used for ornament, which are contained in the same collection whence the former were derived. And first of—

PRECIOUS STONES.

Of these I found seven varieties, at least so many according to the classification of the jeweller, though they are not all distinct mineralogical species, viz. sapphire, beryl, turquoise, garnet, amethyst, clear rock-crystal, and chalcedony. But from the character of the settings of these gems they plainly belong to very different epochs. The determination of the dates when they were used as ornaments, therefore, is altother a question for the antiquarian, and I do not know to what periods these individual specimens are referred; but, with the exception, perhaps, of some of the articles of crystal, none of them seem to belong to that of the original Celtæ, the makers and users of the bronze and gold objects above examined. Some of the amethysts occurring in crosses and similar ecclesiastical relics, are merely the uncut terminations of quartz crystals of the common form, no part of the prism, but merely the hexagonal pyramid being visible. I may mention also here, that the sapphires, which are small and uncut, have in all probability been found in the Co. Wicklow, with rolled pebbles of the mineral occurring in which county they agree perfectly in external characters.

* It is curious to find that up to rather a late period the opinion prevailed that (the compound) steel was only a purer variety of iron. Thus, we read in the Margarita Philosophica (Basil, 1523), "Chalybs est ferrum purgatum et depuratum per ignitiones et extinctiones multas; unde efficitur unctuositas minoris, et faciliús quam ferrum frangitur, nec omnino in pondere æquiparantur."

AMBER

Is the material from which many of the very earliest ornaments of Celtica and Scandinavia were manufactured, according to Worsaae, who refers such to the primeval or stone period; and of these the Royal Irish Academy possesses many specimens, both worked into beads, and in rude, unshapen lumps, none of them, however, of large size. Four of the beads which I examined, of different degrees of transparency and colour, were quite unchanged in chemical properties, and in appearance presented nothing at all remarkable, except one, which, on being split, was found to be white and nearly opaque (wax amber) in the interior, while the exterior, including the surface of the hole piercing it, was orange-yellow and transparent, like the more ordinary variety of this substance, the change extending to the depth of about one-twentieth of an inch. This must, I imagine, have been the result of age; unless indeed the bead had at some time been immersed in oil, or any other similar fluid, which had penetrated it to the extent described.

JET.

Ornaments of this material, belonging to the same primitive people as those of amber, are not uncommon in the north of Europe. Two or three fragments examined proved to be, as one would naturally expect, unaltered specimens of this variety of coal.

COLOURED GLASS BEADS.

Beads of glass, either uniformly stained of a single colour, or, in some instances, exhibiting a second colour arranged in spots and streaks upon the first, are frequently found, especially in the tumuli of England and Denmark; and seem to have been regarded not only as personal orna-

ments, but also as amulets or charms, and as such to have been deposited with the dead. They occur of several distinct colours; but the most ordinary, at least of those in the Museum of the Royal Irish Academy, are two shades of blue, a black (in reality intensely deep green), a very pale sea-green, and white; of each of which I received a specimen for qualitative analysis.

No. 1 was a very fine, dark-blue bead, quite resembling good modern cobalt glass in colour, but full of minute air bubbles. By fluxing with an alkali, solution in muriatic acid, and the application of the usual re-agents, the colouring matter was found to be oxide of cobalt, but the glass also contained a trace of copper. Whether the latter was accidental, or, being known to tinge glass blue or green, was added with the intention of improving the colour, it would be impossible to say. It was contended by Gmelin* that the blue glass of the ancients was not stained by cobalt, but iron (that it was analogous to ultramarine), and an ancient specimen of a sapphire blue colour, analysed by Klaproth,† gave no indications of the former metal; but Sir H. Davy‡ found cobalt in all the glass vessels of this colour from the tombs of Magna Græcia, and the same colouring material has been detected in the beads found upon Egyptian mummies. The present is, therefore, but an additional instance of the use of this metal for a single purpose being known long before it or any of its preparations had been obtained in a state approaching purity.

No. 2. A bead of so dark a bottle-green colour as to appear at first sight quite black and opaque. In very thin splinters it was translucent, and of the above tinge. The colouring material was oxide of iron, used in very large quantity, and traces of manganese were also distinctly

* Götting. gel. Anz., 1776. † Beiträge, p. 144.
‡ Philosophical Transactions, 1815, p. 108.

perceptible. The specimen was from Templepatrick, in the county of Antrim; was nearly spherical, well shaped, and had a finely polished surface.

No. 3 was a blebby, light-blue bead, verging on green. But for the air bubbles contained in it, it would have been nearly transparent.—From Kilmainham. The colour was owing to oxide of copper; and both in the staining of the glass, and in forming the bead, the specimen was a very rude result of early art.

No. 4 was a flattened bead, also from Kilmainham. It was more nearly transparent than any of the others, and had only a very faint tinge of sea-green, so pale that it probably was not intentional; on the contrary this would seem more likely to have been an attempt at colourless glass, which we know was more highly valued by the ancients, at least in the south of Europe, than any other. I could detect no colouring metallic oxide in the present specimen, except the merest trace of oxide of iron.

No. 5. An opaque white bead, of a flattened form, from the same locality with the last. On examination it proved not to be glass at all, but pure crystalline white marble (carbonate of lime), which had been very neatly cut to the required shape, and the surface well polished. This material has not, I believe, been hitherto noticed among those employed in making these primitive ornaments.

From their occurrence at the same locality with the iron weapons above mentioned, which M. Worsaae considers to be certainly relics of the Norse "vikings," these beads would seem probably to have come over here from Scandinavia, and not to have been of native Irish manufacture. But whence the primeval inhabitants of Denmark and Norway derived their supply of such trinkets seems to be quite unknown. Italy and Egypt have both been mentioned as possible sources, principally on the ground that similar arti-

cles have been found in both countries, and that both possessed the art of making glass at a very early period; but as yet nothing certain appears to have been determined, beyond the general opinion that they came from the south of Europe, the method of making them being unknown over the whole of the north. The results of my examination agree very well with those of some of the specimens of Klaproth and Sir H. Davy;* but further investigation of the Celtic articles (and indeed of those from the south of Europe) would be important in order to elucidate the history of this ancient manufacture, as it is only from the qualitative analysis of numerous examples varying in date and locality that we can hope to derive any valuable general information on the subject.

Another highly interesting branch of an inquiry as to the means of decoration possessed by the ancients is that concerning their

PIGMENTS,

and hence I have been most anxious to examine such remains of this kind as might be in existence in Ireland; but have only succeeded as yet in obtaining specimens (used in fresco painting) from a single locality, namely, Slane Abbey, in the county of Meath; and these probably do not belong to an earlier date than 1512, as the Abbey, originally established in the seventh century, was refounded in that year. There were six varieties of colour examined, all of which had been laid on upon a uniform white ground of about the one-twentieth of an inch in thickness, or perhaps a little thicker, as part of the ground had, no doubt, been lost in removing the stucco from the walls. The coats of colour were a little thinner, but were not uniform, being thicker in some places than others; they were all mixed with an oily substance used in very small quantity, which was soluble in alcohol

* Loc. cit.

and ether, and reprecipitable from the former on the addition of water; want of material prevented the possibility of determining its nature more accurately. The ground or basis upon which the colours were laid consisted of carbonate of lime mixed with a little silica, or rather white siliceous clay. It, as well as the colours themselves had been carefully and finely ground. The results with respect to the individual pigments were as follows:—

No. 1 was a dull red, almost a brick colour, but somewhat brighter. Heated before the blowpipe on charcoal, it fused into a black shining bead, and in the reducing flame gave globules of a soft, white metal, which on examination proved to be lead. Digested in dilute nitric acid, it partially dissolved under effervescence. The solution gave with hydro-sulphuric acid a black precipitate of sulphuret of lead, and with ammonia after filtration a slight reddish-brown one of peroxide of iron, containing a trace of alumina. On fluxing the residue insoluble in nitric acid with carbonate of soda, it was found to consist of highly ferruginous silica. Hence this colour appears to be an impure oxide of iron, or perhaps iron ochre, mixed with carbonate of lead.

No. 2. A pale yellow verging on white. Before the blowpipe it behaved nearly in the same manner as the red, but became considerably darker by the first application of the heat, before fusion. Treated in the same way as the last, it proved to be a light yellow ochre, mixed with a large proportion of ceruse, and containing a good deal of the oily matter with which the colours appear to have been mixed.

No. 3. A light blue; the only one of the colours which had any pretensions to brilliancy. In the specimens which I had, it invariably occurred over a coat of the red, No. 1; hence it probably was picked out or cut through in some places, so as to produce a pattern of blue in relief on the red ground.

It dissolved to a great extent with effervescence when heated in nitric acid, and the solution, on adding excess of ammonia, gave a pale blue solution of oxide of copper, and a copious precipitate of oxide of lead. The insoluble residue was fluxed, and consisted of silica, with alumina, and oxide of copper, and probably an alkali. Hence this colour was partly a copper frit of the same kind with that found by Sir H. Davy, in the blue pigments examined by him in Italy, but it differs from these latter in that some of the copper exists in a state soluble in acids, I believe, as carbonate. Before the blowpipe, this and all the remaining colours yielded metallic lead when heated on charcoal, and empyreumatic products in a closed glass tube.

No. 4. White. This turned out, on solution in nitric acid, and the application of the proper re-agents, to be slightly impure carbonate of lime, the same, in fact, as the basis of all the colours, though laid on in a separate layer. The fact of this being the white employed, and not white lead, which yet was mixed with the other pigments, would seem to indicate either that the latter substance was prepared of so impure a character, as not to be a good white, or that it was known to darken by long exposure, where traces of sulphuretted hydrogen were present in the atmosphere, and therefore was rejected as not a permanent colour.

No. 5. A greyish black. It became white by the action of the blowpipe flame, and dissolved in nitric acid with copious effervescence, leaving a slight carbonaceous residue of a black colour, perfectly dissipated, with the exception of a trace of silica, by heating to redness for an instant on platina foil. The nitric acid solution contained nothing but lime. This, therefore, was a mixture of carbon in some form, probably lamp-black with carbonate of lime.

No. 6 was a dull brown, which proved to be an ochre, containing silica, alumina, lime, and a large quantity of

oxide of iron, analogous to Nos. 1 and 2, but of a different shade. It was mixed, like them, with carbonate of lead.

Such are the results of the examination of these colours, results which, as far as they go, agree to a remarkable extent with those of Sir H. Davy's important investigation* of the ancient Roman pigments above referred to. The materials used are in each instance the same, or very nearly so, which is not so much to be wondered at, however, when we consider that most of these materials are the commonest and most easily obtained substances for the purpose, requiring but little preparation, and of a durable and stable character; hence naturally selected by the early artist, and, when once in use, not likely to cease to be so from the knowledge of them dying out, as that of difficult and rare preparations may easily do. Two points of difference are, however, to be found between the Roman pigments and these Irish ones, namely, the use of an oily material for mixing the colours from Slane Abbey, whereas no such was employed by the Romans in their fresco paintings; and the occurrence in the former of large quantities of ceruse, or white lead, which, although known and described by Pliny and Vitruvius as a common colour, was not found by Sir H. Davy in any of the specimens examined by him; both which circumstances tend to show the more modern character of the Irish pigments.

Besides the antiquities above described, I have obtained specimens of, and made some experiments upon, other classes of Celtic remains, as the materials of the ancient cinerary urns, the human bones burned and unburned from sepulchral tumuli, ancient leather, &c.; but as yet the results are too few and incomplete for presentation to the

* Philosophical Transactions, 1815.

faculty. Indeed, it will be seen that the present investigation is very far from exhausting the subject with respect even to the classes of objects already discussed, rather serving to show some archæological questions which may be advantageously asked by the assistance of chemical research, than affording answers to any of those already debated; yet the analyses and experiments above described are not, I think, absolutely barren in results of interest, and at least put on record a number of facts concerning the materials employed in Ireland at a very early period for various purposes of the arts, which may possibly in some degree assist the researches of archæologists.

THE END.